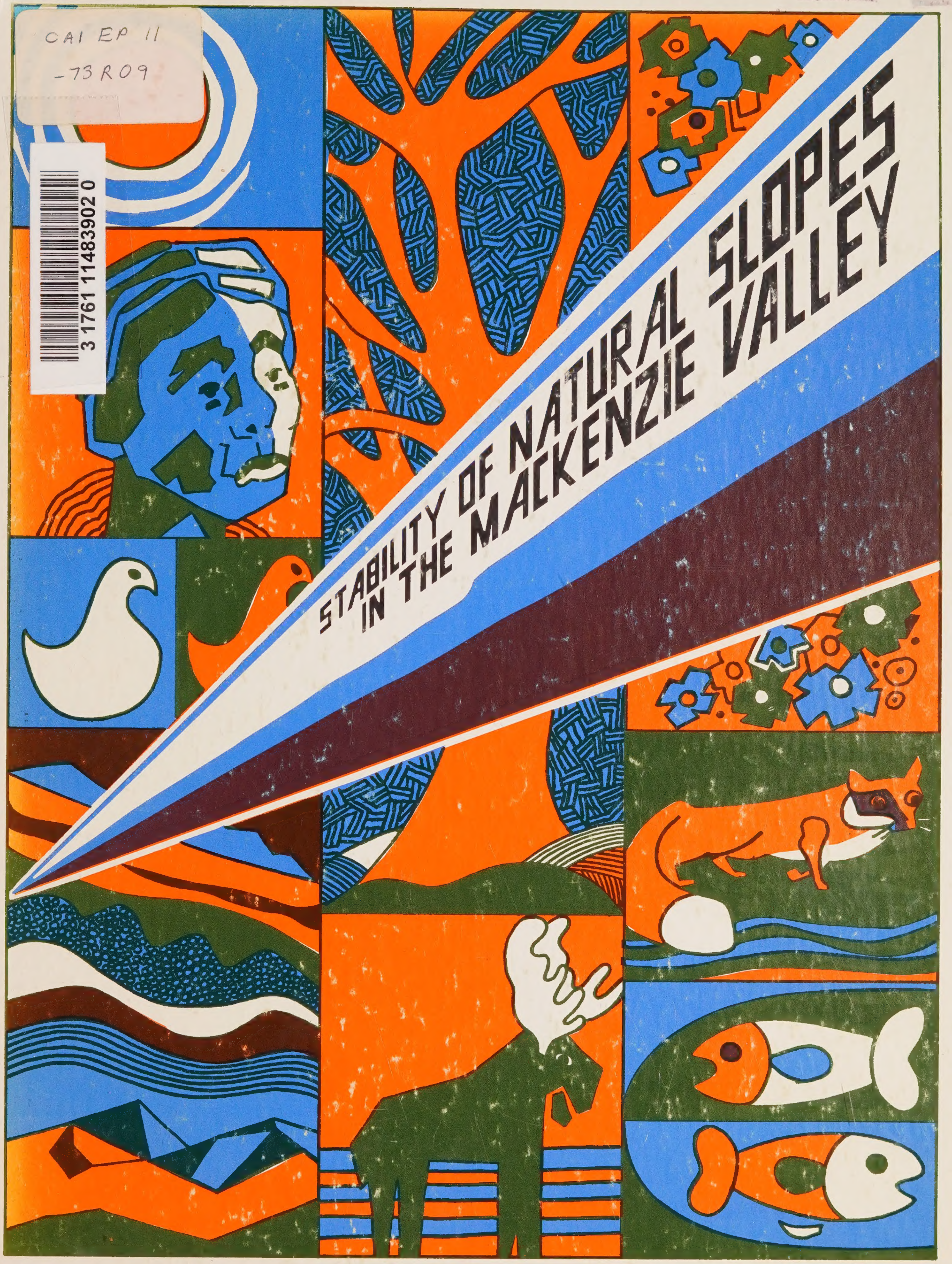
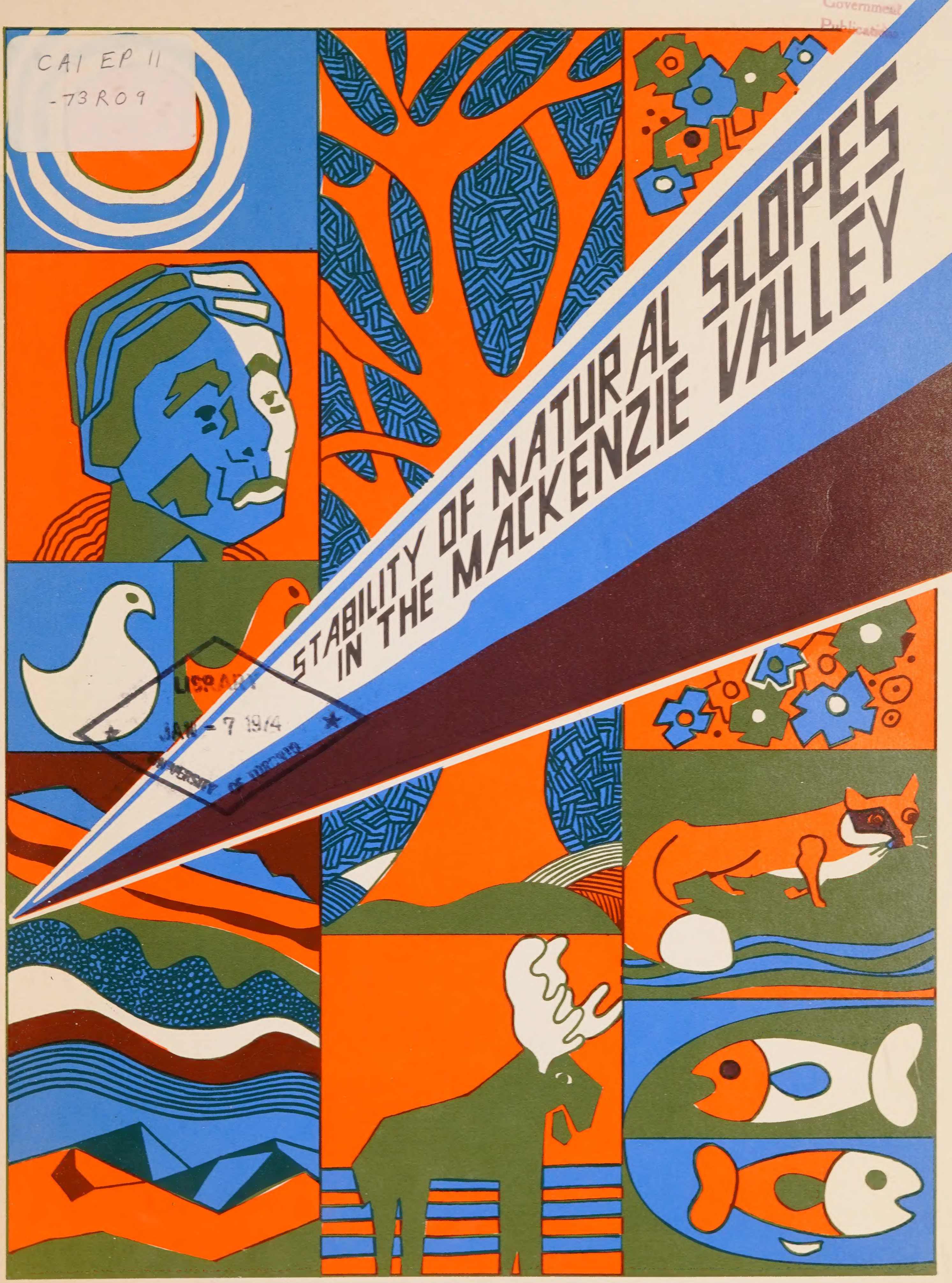
STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY




STABILITY OF NATURAL SLOPES
IN THE MACKENZIE VALLEY

THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

by

J.A. Code

Terrain Sciences Division
Geological Survey of Canada

Department of Energy, Mines
and Resources

for the

Environmental-Social Program
Northern Pipelines

July 1973

Canada

Environmental-Social Committee
Northern Pipelines,
Task Force on Northern Oil Development
Report No. 73-9

Information Canada
Cat. No. R72-10573

10 maps

The data for this report were obtained as a result of investigations carried out under the Environmental-Social Program, Northern Pipelines, of the Task Force on Northern Oil Development, Government of Canada. While the studies and investigations were initiated to provide information necessary for the assessment of pipeline proposals, the knowledge gained is equally useful in planning and assessing highways and other development projects.

TABLE OF CONTENTS

FIGURES

Illustrating types of slope failures found in the Mackenzie Valley.

SUMMARY

A program of mapping stability of river banks of the Mackenzie River and its tributaries within the adjacent plains region was carried out in ten map areas between Fort Simpson and Fort Good Hope, N.W.T. Mapping was done according to an engineering-geological classification system which relates certain conditions of stability and topography to the geology. In general, slope failures are of two main types - shallow active layer failures, and larger scale multiple retrogressive slides characteristic of high banks of Quaternary sediments and Cretaceous Shales.

As potential river crossing sites are evaluated for pipelines or roads, factors to be considered should include the following:

- the retrogressive nature of the larger types of slides
- the abrading action of river ice on river banks and bottom during break-up
- the adverse effects of forest fire on stability of slopes
- the effects of ice jamming in raising upstream water and ice levels

INTRODUCTION

A rational approach to the planning, design and construction of transportation systems in the Mackenzie Valley must take into account the mass wasting of sloping terrain, particularly of slopes forming the sides of river valleys. The overall objective of this project is to provide certain geologically based information which will assist in efforts to minimize the environmental disturbance associated with future construction on, and adjacent to, such slopes.

The information presented on the appended map sheets and in the text represents the results of a field mapping operation initiated during the summer of 1971 and continued in 1972. The maps provide an inventory of the river banks of the Mackenzie River and its main tributaries within the adjacent plains region. They are classified according to a system, shown in the legend, which relates types of failures to geologic and topographic factors. Helicopter borne field mapping was supplemented with ground verification as required. Field mapping was done on high level air photos and 1:50,000 scale hydrographic charts. The information was reduced and compiled on the appended 1:250,000 scale topographic sheets. The following map areas were covered:

95 H, I, J, O, N

96 C, D, E

106 H, I

In conjunction with the inventory-classification aspect of the mapping program, a qualitative assessment has been made of the geomorphic processes and the failure mechanics associated with mass wasting. In addition, the significance of river bank erosion as it applies to engineering activities has been considered.

REVIEW OF CURRENT KNOWLEDGE

Because of the hazards often associated with landslides and slope failures, considerable effort has been expended in exploring the causes of these phenomena and in the prevention and remedial treatment of them. Analytical methods for determining the stability of slopes in terms of factors of safety form an integral part of the discipline of soil mechanics. Most of these techniques have been developed for application to unfrozen soils, less being known of the failure mechanics associated with mass movements in permafrost terrain. The recovery and testing of undisturbed borehole samples of frozen soil and monitoring of pore pressure conditions are required in order to do such analyses and costs of these operations are considerably increased because of the isolated conditions.

Recent studies of failure mechanics at selected sites along the Mackenzie River include those initiated in 1972 by Dr. N. Morgenstern and Mr. E. MacRoberts of the University of Alberta.

CLASSIFICATION SYSTEM

A number of classification systems have been devised in association with studies of landslides and related phenomena. In general such systems have their roots either in the earth sciences or the related engineering discipline of soil mechanics. The classification system used in this study attempts to straddle the boundary between geology and engineering and is tailored to the reconnaissance - inventory nature of the mapping operation to which it was applied.

The system is intended to serve the practical purposes of engineering and construction, and for this reason the different scales of mass movement are given emphasis. This approach is facilitated by the two orders of magnitude of material displaced as slopes fail. The smaller failures are confined to the shallow active layer, the top few feet of annually thawed ground overlying permafrost. The much larger slides or slumps, and in some cases flows, involve displacement of an entire river bank which may be 100 feet or more in height. In such cases, frozen as well as thawed soil and rock may be displaced. The magnitude of the environmental hazard bears a parallel relationship to the scale or size of failure. The primary subdivision is made in terms of the geology since a relationship exists between mode of failure, strength properties of earth materials, and the age of deposition. Hence a degree of predictability of the bahaviour of slopes, can be established if the geologic age and composition of the soil or rock in each area are known.

This classification system (see Table 1, page 18) is a revision of one divised to describe slope failures in the Fort Good Hope - Sans Sault Rapids area (Isaacs and Code, 1972).

SLOPE EROSION - GENERAL

Retreat of river valley slopes occurs as a result of geomorphic processes that can be categorized either as mass movement or mass transport. Mass movement refers to the downslope movement of earth materials under the incluence of gravity without the assistance of a transporting media. Mass transport, on the other hand, refers to the transport of fragments of earth materials suspended in a transporting medium, either water, ice or wind. These two types of processes do not necessarily act independently, and may be in effect either at the same time or sequentially.

In the area mapped, mass movement is expressed in the following terms:
- falls: rock falls and soil falls
- slides: slumps, translational slides, detachment slides
- flows: earthflows, solifluction

The meanings intended by this terminology are explained below:
(i) The terms "rock fall" and "soil fall" are almost self-explanatory and indicate free fall motion of fragments with some related rolling or sliding.

(ii) "Slides" are types of mass movement in which the detached mass is not significantly deformed while in motion. They are initiated by failure either in shear or tension along a finite failure plane. "Slumping" refers to rotational failure in shear with a backtilting of the displaced unit. "Translational sliding" refers to movement along a planar surface which in permafrost terrain is probably an unfrozen clay or silt layer within or below the permafrost layer. The term "detachment slide" (O.L. Hughes, 1972) refers to downslope displacement of the thawed active layer of organic material, thawed soil, or weathered shale. "Earthflow" refers to the downslope displacement of earth materials which behave as viscous fluids during motion. Very rapid earthflows are sometimes referred to as mudflows. The term solifluction has been defined as "slow flowing from higher to lower ground of masses of waste saturated with water". It refers to a periglacial phenomenon, and rates of movement are generally in the order of 2-5 cm per year (Hamelin and Cook, 1967). "Slopewash" refers to the downslope mass transport of materials suspended in water without the organization of drainage into a system of rills and gullies. "Gully erosion" or "gullying" is a similar phenomenon but one in which the water and suspended materials are carried in channels.

SLOPE STABILITY IN THE MACKENZIE VALLEY

In any stability analysis of slopes, either natural or man-made, certain factors or conditions must be taken into account. These are (a) the strength properties of the materials (b) hydrological conditions (c) topography (d) active erosional processes which may alter the stability.

In periglacial regions factors which relate to the presence of ground ice and to the severe climatic conditions should also be considered.
(i) The presence of the impermeable permafrost layer just below the ground surface causes surface water to drain laterally rather than being partially absorbed into the ground as in temperate climates. Hence higher moisture contents are found in the active layer than are found in equivalent surface layers of non-permanent terrain. These higher water contents result in a lowering of shear strengths of the soils, thus reducing their overall stability on inclined terrain.

(ii) River ice carried downstream during spring break-up, abrades the river banks at various levels, removing vegetative cover, steepening and unloading the toe of slopes thus generally reducing the stability.
(iii) Due to the presence of ground ice, moisture contents in fine grained (cohesive) soils are often higher than the liquid limit. Such soils when thawed become highly mobile.
(iv) Slumped or sliding blocks of frozen ground usually remain relatively undeformed during the period of movement. Deformation would proceed if thawing were to occur after failure.
(v) Within certain limits, the shear strength of soil in the permafrost layer increases in some proportion to the amount of ground ice present, and in proportion to decreasing ground temperature.
(vi) Melting ice wedges adjacent to slopes may provide planes of weakness which then develop into tension cracks or channels capable of capturing surface run-off and initiating gullying.
(vii) Regeneration of burnt organic cover is slower than in more temperate climates. This slows the rate of stabilization of slopes failing because of the loss of organic cover.
(viii) Ice jamming in rivers during spring break-up has a number of effects which tend to reduce the stability of adjacent slopes. These effects are:
- raising water levels upstream reducing effective (intergranular) pressures in the soils
- scouring of the river bed below the ice which may unload the toe of adjacent slopes
- raising the level at which ice scours the upstream banks
- rapid drawdown of upstream water levels when an ice jam breaks up
- increased scour of river bed and adjacent slopes downstream of an ice jam when it is released

(ix) South facing slopes tend to thaw and fail at a faster rate than north facing slopes. Material displaced into the river bed may tend to divert the stream channel to the south and cause undercutting of the north facing slope which then becomes unstable because of accelerated oversteepening. This effect is particularly noticeable in the lower reaches of the Mountain River.

INTERPRETATION OF FIELD INVESTIGATIONS

(i) Multiple retrogressive failures are characteristic of glaciolacustrine sediments and Cretaceous shales in river banks more than 100 feet in height. In some places, at least, the material has failed while in the frozen state. Although the backtilting characteristic gives the appearance of rotational failures to many of these slides, a combination translational-rotational mode of failure is indicated.
(ii) Slope failures inland from river valleys are not common south of the Fort Good Hope area. Where they are encountered inland, failure has usually been precipitated by forest fire damage to the organic cover. In such instances flows on inclines as low as 4^{o} were observed.

(iii) Active layer failures usually exhibit a high degree of deformation or plasticity and hence fall in the category of "flows".
(iv) Most stream tributaries to the Mackenzie River have the characteristic failure pattern of meandering streams, with unstable slopes on the outside of meander loops. When fire has damaged the organic cover, however, failing banks may be continuous.
(v) The oversteepening of river banks by the abrading action of river ice during spring break-up is considered a major contributing factor in the initiation of landslides.
(vi) Slopes seem to stabilize at about 15° for most soil types although this figure is probably higher for glacial tills. The angle of repose for granular soils is approximately 35°, so that failing soil slopes are usually inclined in the $15\text{-}35^{\circ}$ range. Slopes steeper than 35° generally involve pre-Quaternary materials which have higher cohesion, or Quaternary soils which are temporarily oversteepened and unstable.

ENGINEERING SIGNIFICANCE OF MASS WASTING IN THE MACKENZIE VALLEY

In addition to the usual considerations associated with the siting and design of river crossings, attention should be given to certain factors related to the presence of permafrost and severe climatic conditions in the Mackenzie Valley.
(i) In any location where the organic cover has been damaged or destroyed by forest fires, failures will be initiated on sloping ground and the rate of failure of previously failing slopes will be accelerated. Inland slopes which are otherwise stable will be vulnerable to failure under such conditions.
(ii) Sharp river bends should be avoided as crossing points; meandering streams should be crossed between meander bends.
(iii) As crossing sites are considered in terms of their potential stability, indications of any recent active movement of the slope should not be construed as evidence that a particular slope has been stabilized. Many types of failures are retrogressive and may continue to move inland for thousands of feet.
(iv) Failure planes associated with multiple retrogressive slides are quite deep compared to normal depths used in pipeline trenching operations. Hence movements of blocks of ground in this fashion could displace entire sections of pipe. Since the pipe would be buried below the active layer shallow, active layer slides would be more likely to result in eventual exposure of the pipe and its subsequent settlement.
(v) Support structures for over-water crossings on the tributaries should be designed not only to withstand pressures of ice moving downstream but to withstand pressures of ice backed up from the Mackenzie River when water levels are raised by ice jamming.
(vi) Underwater crossings must be designed for depths of river bed scour which are greater than for normal flood conditions. The effects of ice jamming described earlier, and of ice scour due to high ice loads carried by rivers such as the Great Bear River should be considered.

REQUIREMENTS FOR FURTHER STUDY

The following aspects of slope stability in the Mackenzie Valley require further and more intensive study.

(i) The mechanics of failure of frozen soils in permafrost terrain.

(ii) The significance of seismicity in the initiation of slope failures.

(iii) The relationship between the occurrence of slope failures and annual and seasonal climatic variations.

(iv) Rates of regression of failing slopes.

REFERENCES

Eckel, E.B., and others
1958: Landslides and Engineering Practice; Special Report 29, Highway Research Board, National Academy of Sciences - National Research Council Publication 544.

Fairbridge, R.W., and others
1968: Encyclopedia of Geomorphology; Rheinhold Book Corporation, New York.

Hamelin, L.E., and Cook, F.A.
1967: Illustrated Glossary of Periglacial Phenomena; University of Laval Press, Quebec, P.Q.

Hughes, O.L.
1972: Surficial Geology and Land Classification, Mackenzie Valley Transportation Corridor; Proc. Can. Northern Pipeline Res. Conf., p. 17-24.

Isaacs, R.M., and Code, J.A.
1972: Problems in Engineering Geology Related to Pipeline Construction; Proc. Can. Northern Pipeline Conf., p. 147-177.

Sharpe, C.F.S.
1938: Landslides and Related Phenomena; Columbia University Press, New York.

Skempton, A.W., and Hutchinson, J.N.
1969: Stability of Natural Slopes and Embankment Foundations; Proc. Seventh Int. Conf. Soil Mechanics and Foundation Engineering; State of the Art Volume, p. 291-340.

Terzaghi, K.
1950: Mechanism of Landslides; Application of Geology to Engineering Practice, Berkey Volume, Geol. Soc. Am. p. 82-123.

Terzaghi, K., and Peck, R.B.
1967: Soil Mechanics in Engineering Practice; 2nd Edition; John Wiley and Sons Inc., New York.

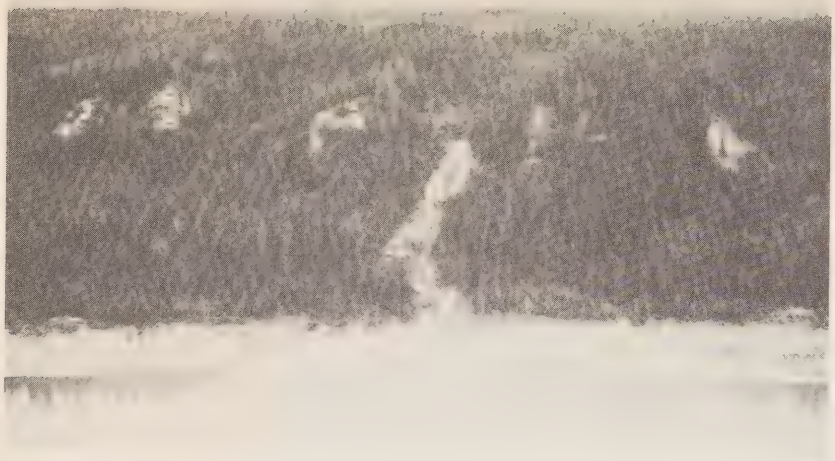


Figure 1 Earthflow, elongate (Qa) Mackenzie River, north of Wrigley.

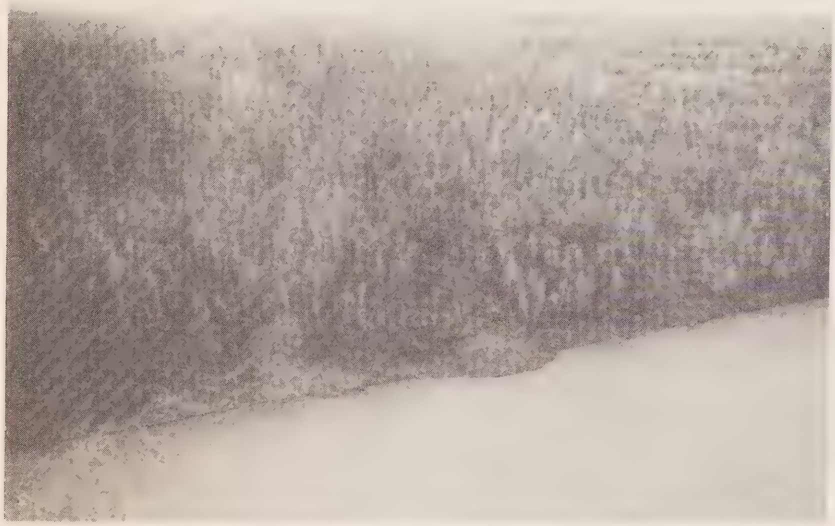


Figure 2 Earthflow, lobate (Qa) Mackenzie River, north of Fort Simpson.

Figure 3 Earthflows in recently burnt area west of Wrigley (Qa).

Figure 4 Closer view of Figure 3.

Figure 5 Detachment slides in granular soil (Qa) Mackenzie River near Blackwater River.

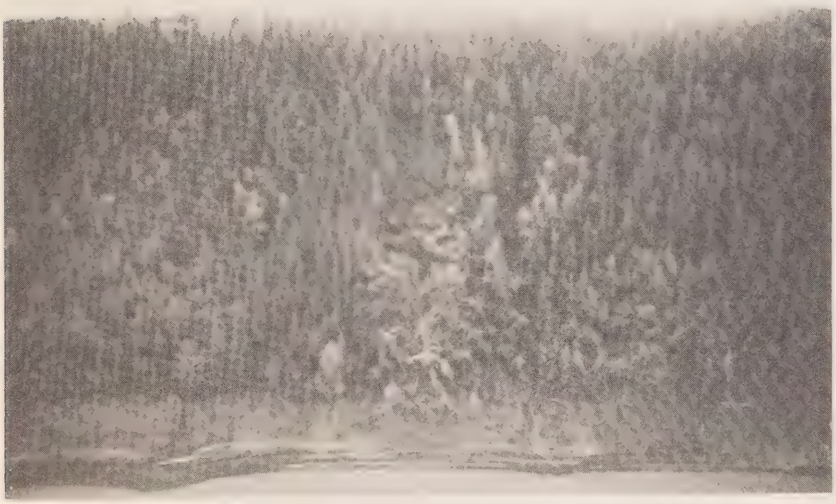


Figure 6 Detachment slide in Cretaceous shale (Ka).

Figure 7 Large scale retrogressive slide; (Q1) Mackenzie River near Root River.

Figure 8 Large scale retrogressive slide; (Q1) Mackenzie River near Root River.

Figure 9 Large scale retrogressive failure; Quaternary sediments (Q1) Mackenzie River opposite Fort Norman.

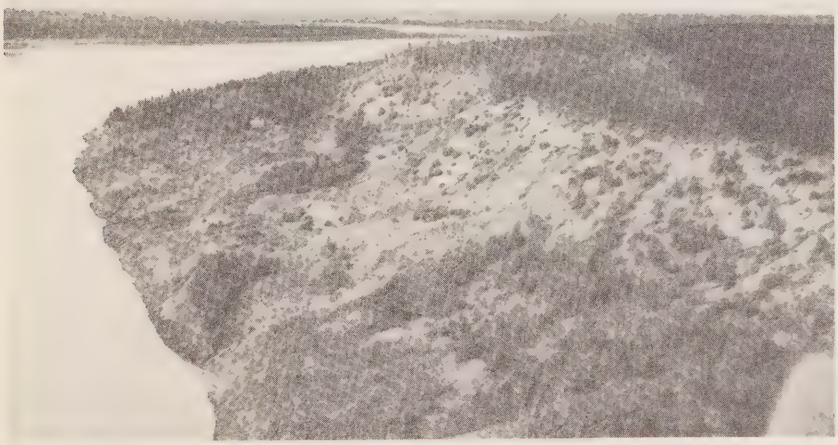


Figure 10 Large scale retrogressive slides, Quaternary sediments (Q1) Mackenzie River south of Fort Norman.

Figure 11 Large scale retrogressive failure in Cretaceous shale (K1) Arctic Red River.

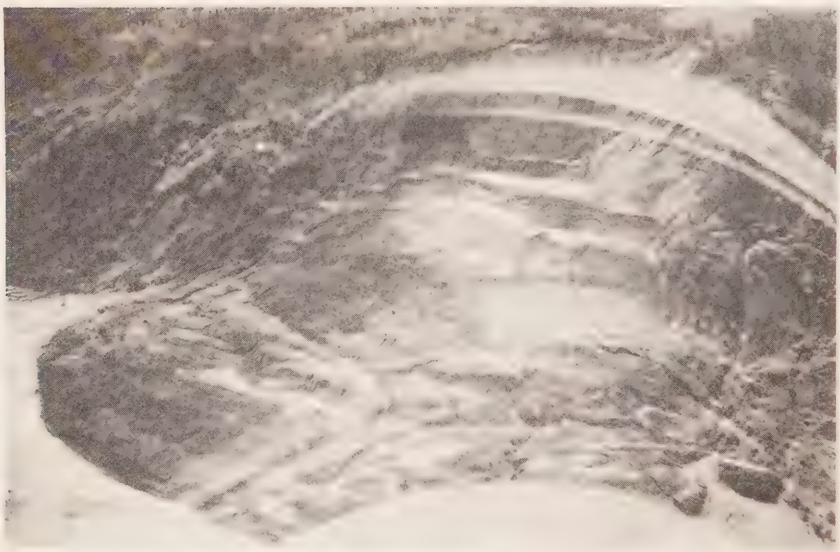


Figure 12 Large scale retrogressive failure in Cretaceous shale (K1) Mountain River.

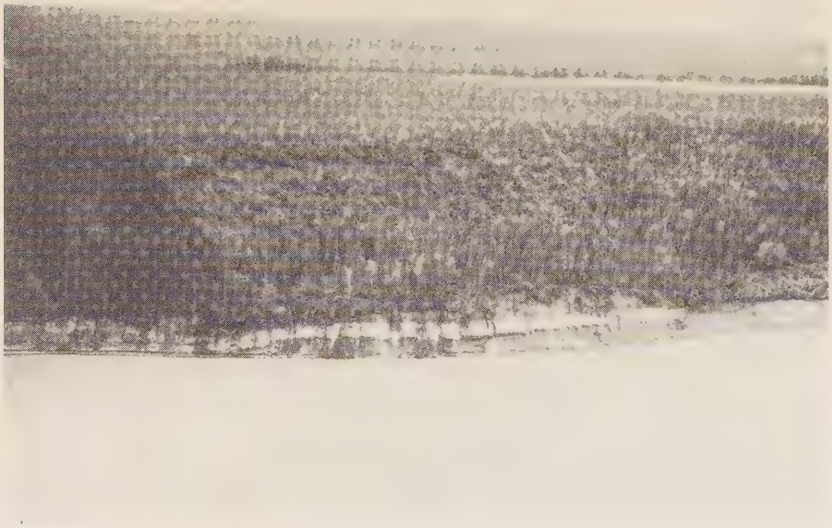


Figure 13 Large scale slumping in Tertiary sediments (Te) Mackenzie River south of Fort Norman.

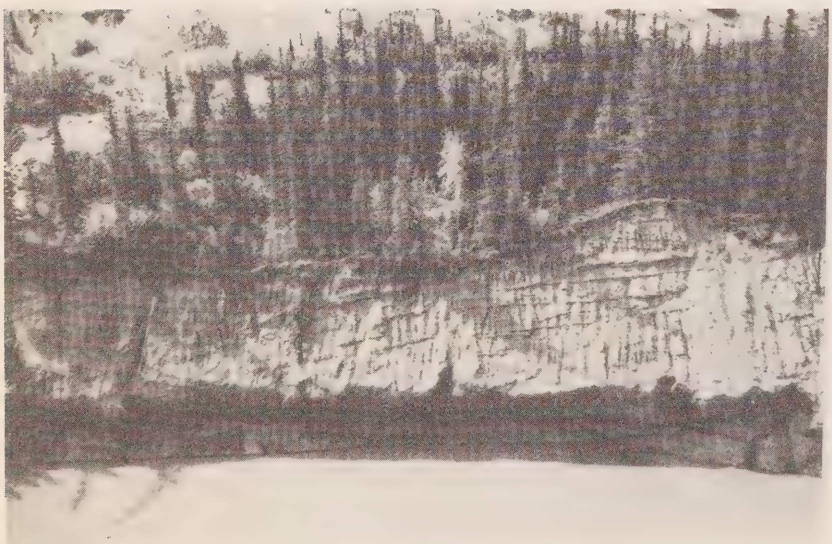


Figure 14 Undercutting of detached frozen slumped block (Q1) Mackenzie River north of Sans Sault Rapids.

Figure 15 River bank in Devonian sediments (D) Liard River.

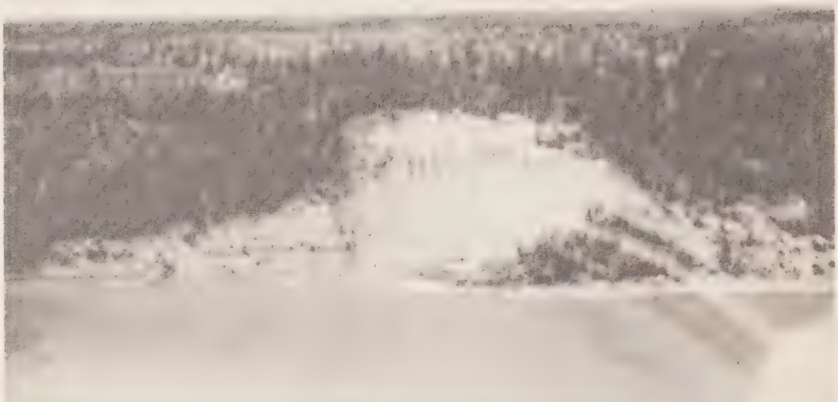


Figure 16 Slump in Devonian sediments (D) Liard River.

Figure 17   Large scale multiple retrogressive slide (Q1) Mackenzie River north of Fort Simpson.

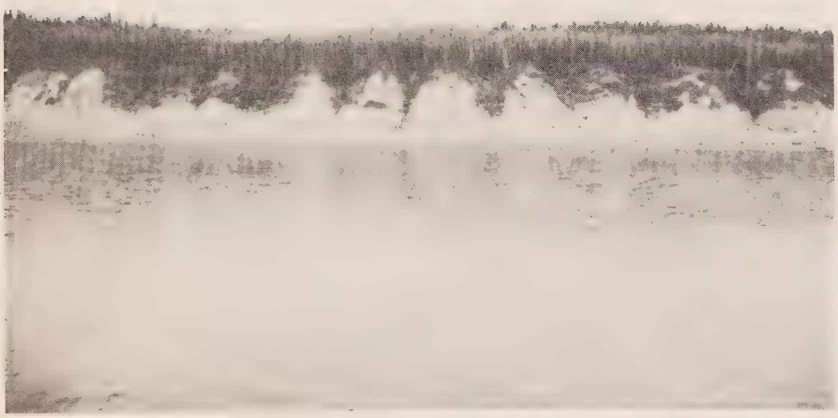


Figure 18   Gullying in glacial till (Qa) Mackenzie River south of Fort Simpson.

TABLE 1 - RIVER BANK STABILITY MAPS

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible, some mass transport of beach and lower slope material by water and river ice.	Stable slopes, vegetated, usually 15° or less. Burnt areas unstable at 5° or less.
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earth-flows, detachment slides, solifluction. Gully erosion and slopewash.	Slope angle $15\text{-}35^{\circ}$. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high.
		Ql	Large scale retrogressive failures (translational slides, slumps, flows); usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands.	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement; sometimes consist of frozen soil and often exhibit backward tilt.
Tertiary	Weakly cemented mainly clastic sediments - sandstone, limestone, conglomerate, shale.	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope; talus accumulation at toe consisting of granular and fragmented rock debris.
		Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet. Weathered slopes generally less than 35°.
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone.	Kl	Large scale retrogressive failures of high shale banks.	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping.
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptible to gullying and slumping.	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls ($< 35^{\circ}$).

GSC MAP 3-1973

RIVER BANK STABILITY MAP

To accompany

THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

by J A Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible some mass transport of beach and lower slope material by water and river ice	Stable slopes, vegetated, usually 15° or less Burnt areas unstable at 5° or less
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments (Soil cover)	Qa	Mass movement confined to active layer Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction Gully erosion and slope-wash	Slope angle 15-35 Displaced material usually highly deformed due to high moisture contents in active layer Slopes usually less than 100 feet high
		Ql	Large scale retrogressive failures (translational slides, slumps, flows), usually accompanied by large scale gullying Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height Displaced blocks usually relatively undeformed during movement sometimes consist of frozen soil and often exhibit back-ward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, lime-stone conglomerate, shale	Te	Gullying, slope wash, infrequent slumping	Moderate to steep upper slope, talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale, weakly cemented sandstone and siltstone	Ka	Gullying slope wash, shallow active layer slides	Bank height less than 100 feet Weathered slopes generally less than 35°.
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock Limestone, sandstone dolomite shale	D	Rockfalls infrequent slumping Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe Softer shales erode to low angle valley walls (< 35°)

NOTES

1 Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments Thicknesses of units not measured

2 Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs

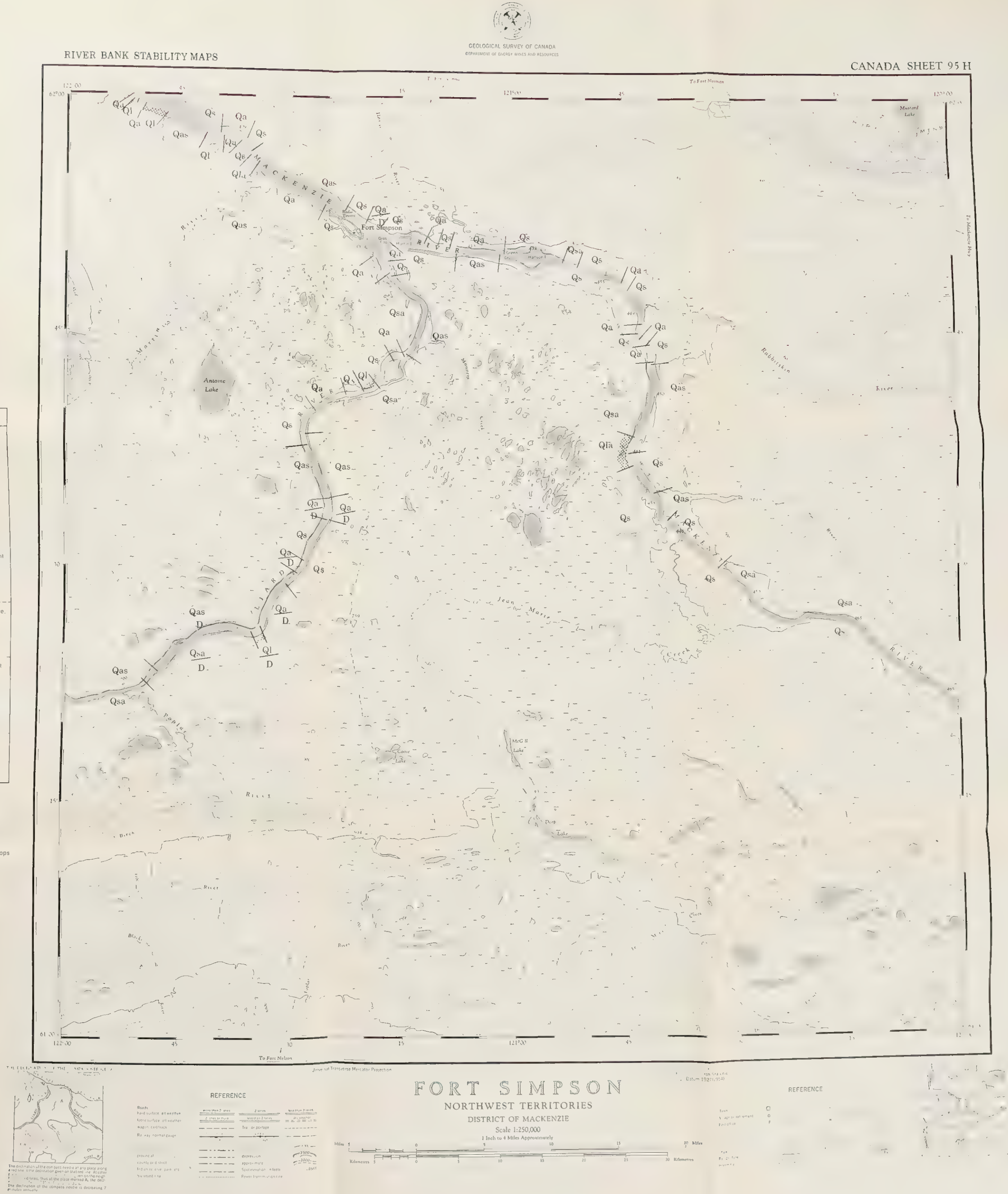
3. Transitions between units are often gradual rather than abrupt, in such instances boundaries are chosen arbitrarily

4 Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J A Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973



Government Publications

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES

GSC MAP 4-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J A Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible, some mass transport of beach and lower slope material by water and river ice	Stable slopes, vegetated usually 15° or less. Burnt areas unstable at 5° or less
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments (Soil cover)	Qa	Mass movement confined to active layer Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash	Slope angle 15-35° Displaced material usually highly deformed due to high moisture contents in active layer Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows), usually accompanied by large scale gullying Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height Displaced blocks usually relatively undeformed during movement sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone lime-stone, conglomerate shale	Te	Gullying, slope wash infrequent slumping.	Moderate to steep upper slope, talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale, weakly cemented sandstone and siltstone	Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet Weathered slopes generally less than 35°
		Kl	Large scale retrogressive failures of high shale banks.	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe Softer shales erode to low angle valley walls (< 35)

NOTES

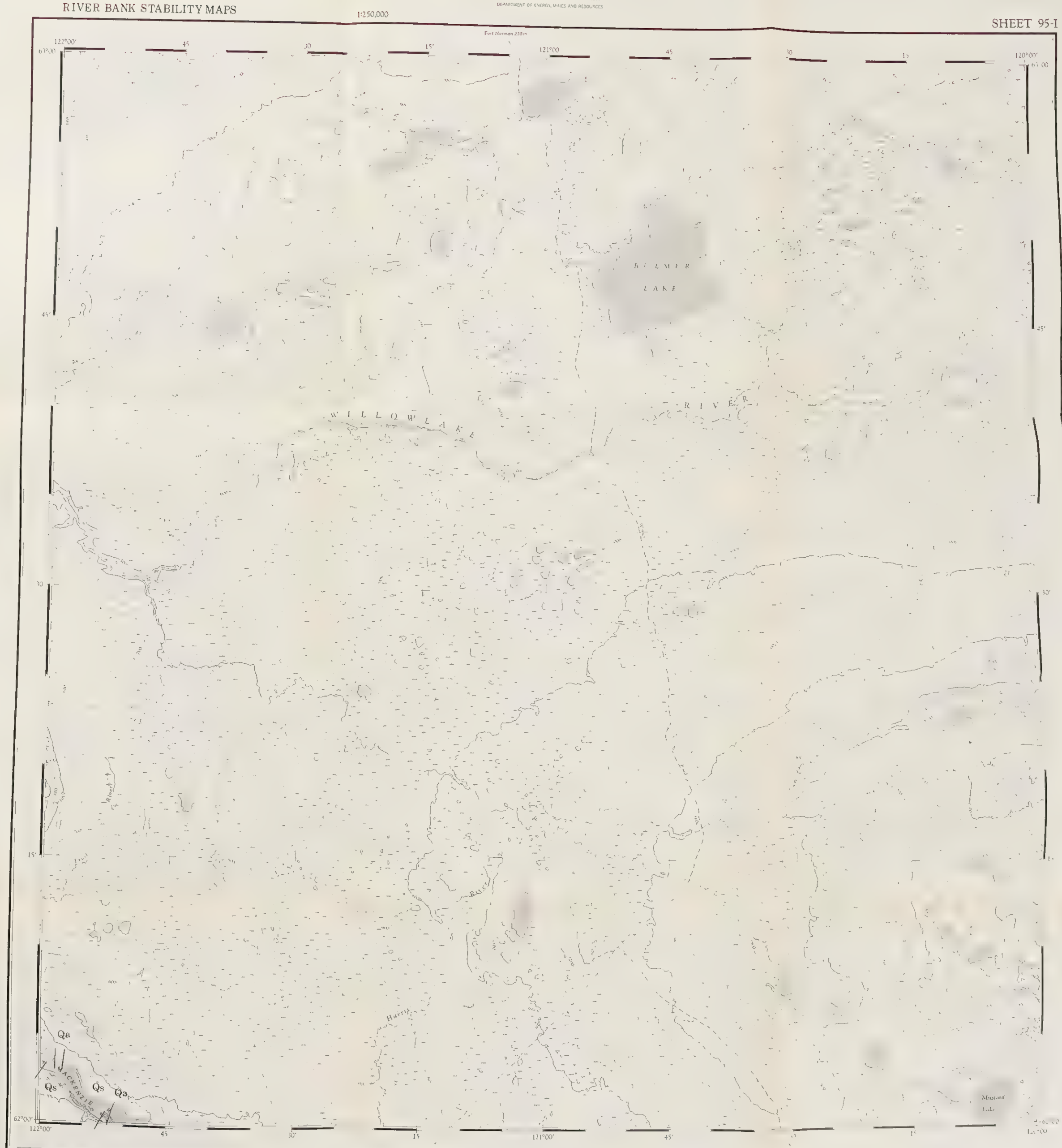
1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured.
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs
3. Transitions between units are often gradual rather than abrupt; in such instances boundaries are chosen arbitrarily.
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

RIVER BANK STABILITY MAPS 1:250,000 SHEET 95-I



REFERENCE

BULMER LAKE

NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE
Scale 1:250,000
1 Inch to 4 Miles Approximately

REFERENCE

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES

GSC MAP 5-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J A Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments (Soil cover)	Qs	Negligible, some mass transport of beach and lower slope material by water and river ice	Stable slopes, vegetated, usually 15° or less. Burnt areas unstable at 5° or less
		Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash	Slope angle 15-35°. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows) usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement, sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone, conglomerate, shale	Te	Gullying, slope wash, infrequent slumping	Moderate to steep upper slope, talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale, weakly cemented sandstone and siltstone	Ka	Gullying, slope wash, shallow active layer slides	Bank height less than 100 feet. Weathered slopes generally less than 35°
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite, shale	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptible to gullying and slumping	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°)

NOTES

1 Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured

2 Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs.

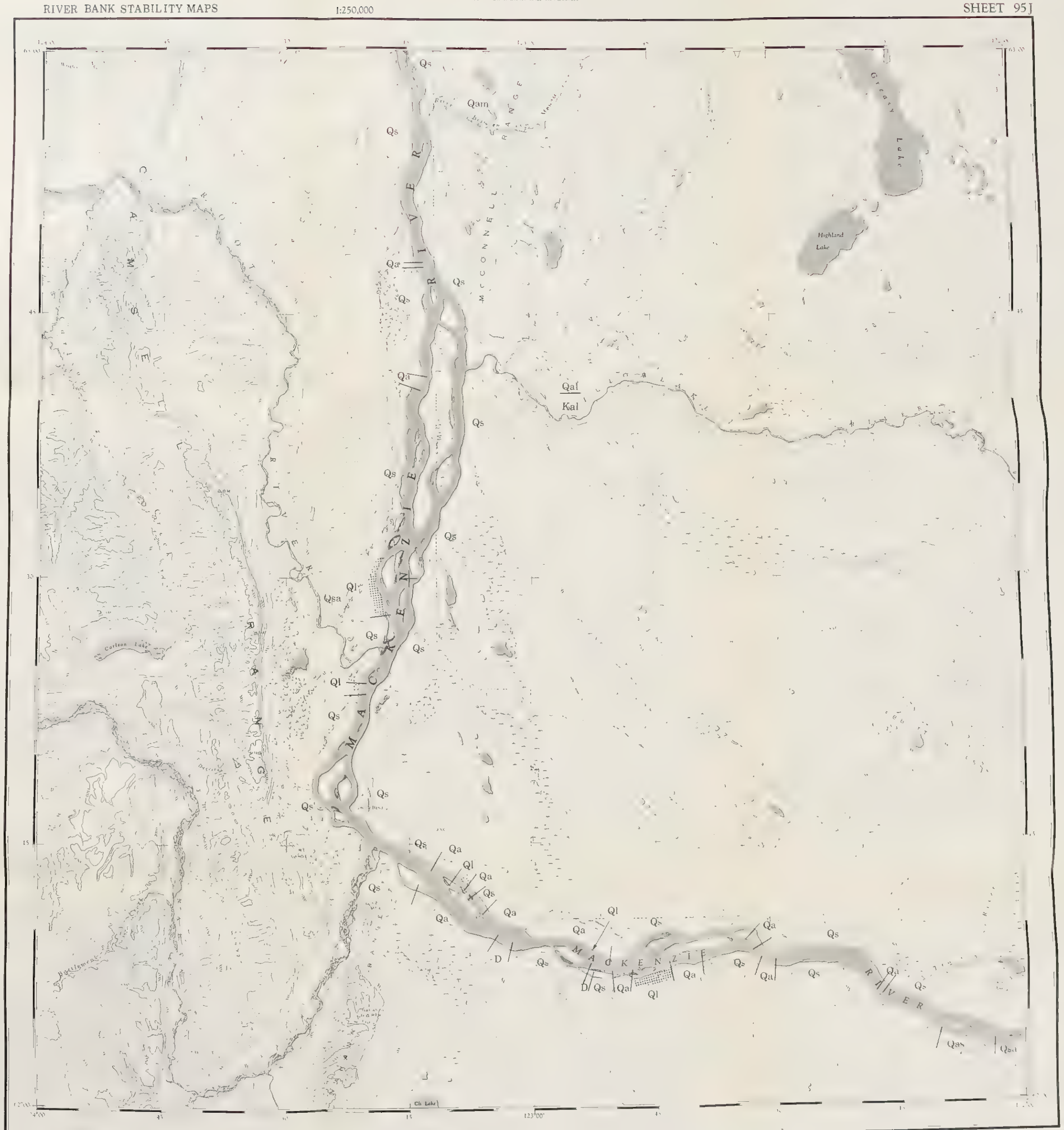
3 Transitions between units are often gradual rather than abrupt; in such instances boundaries are chosen arbitrarily.

4 Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J A Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973



REFERENCE

CAMSELL BEND
NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE

Scale 1:250,000
1 Inch to 4 Miles Approximately

GSC-MAP 6-1973

RIVER BANK STABILITY MAP

To accompany

THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible, some mass transport of beach and lower slope material by water and river ice	Stable slopes, vegetated usually 15° or less. Burnt areas unstable at 5° or less
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash	Slope angle 15-35. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows), usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone conglomerate, shale	Te	Gullying, slope wash. Infrequent slumping.	Moderate to steep upper slope, talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone	Ka	Gullying, slope wash, shallow active layer slides	Bank height less than 100 feet. Weathered slopes generally less than 35°.
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°)

NOTES

1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs.
3. Transitions between units are often gradual rather than abrupt, in such instances boundaries are chosen arbitrarily
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

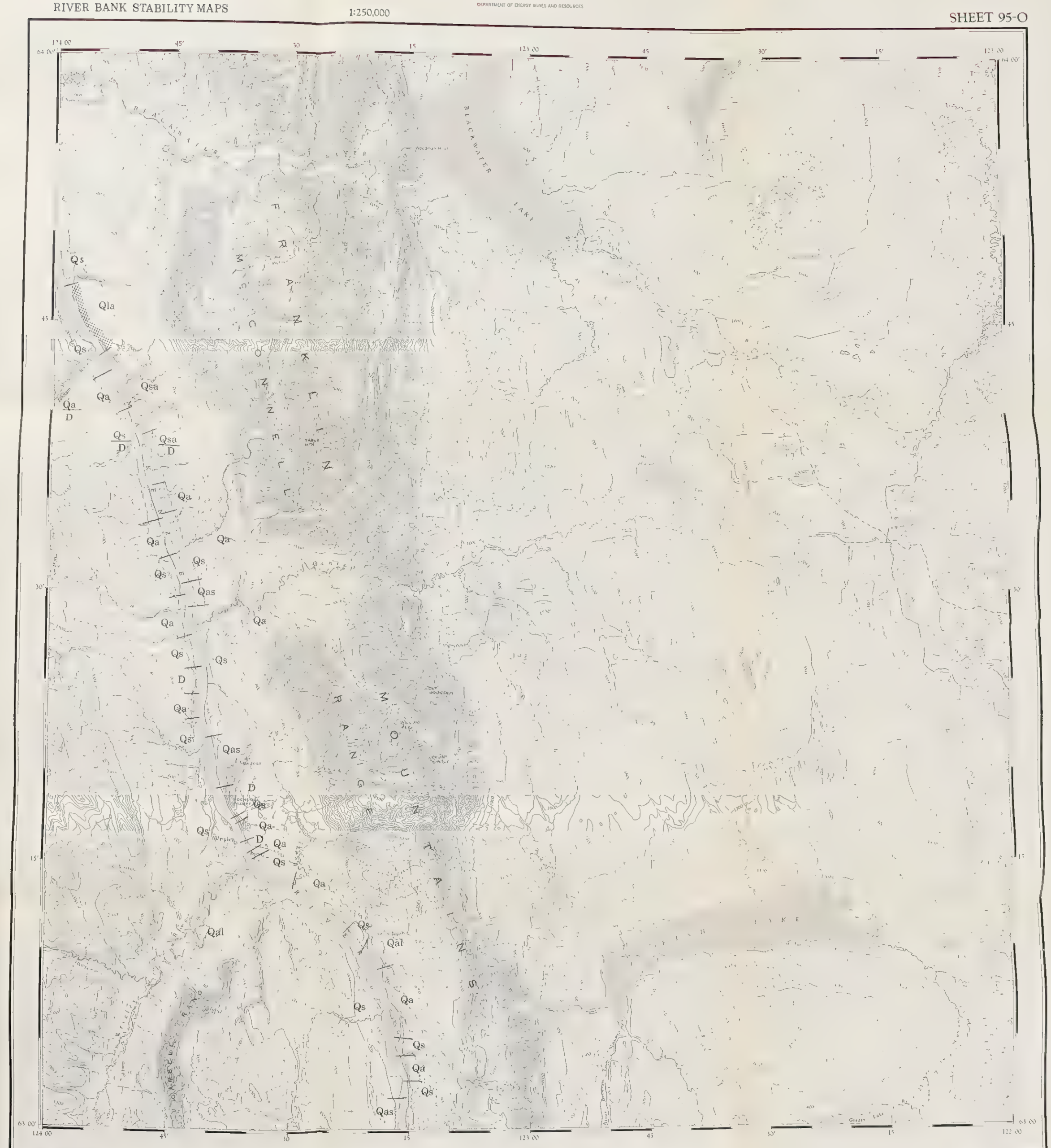
Compiled by J.A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES

RIVER BANK STABILITY MAPS 1:250,000 SHEET 95-O



WRIGLEY

NORTHWEST TERRITORIES

DISTRICT OF MACKENZIE

Scale 1:250,000

1 Inch to 4 Miles Approximately

Transverse Mercator Projection

Government Publications

GSC MAP 7-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments (Soil cover)	Qs	Negligible, some mass transport of beach and lower slope material by water and river ice	Stable slopes vegetated usually 15 or less Burnt areas unstable at 5 or 1
		Qa	Mass movement confined to active layer Failures also shallow in non-permafrost areas Mainly earthflows, detachment slides solifluction Gully erosion and slope-wash	Slope angle 15 35 Displaced material usually highly deformed due to high moisture contents in active layer Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides, slumps flows), usually accompanied by large scale gullying Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height Displaced blocks usually relatively undeformed during movement sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone conglomerate, shale	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale, weakly cemented sandstone and siltstone	Ka	Gullying, slope wash, shallow active layer slides	Bank height less than 100 feet Weathered slopes generally less than 35°
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented resistant sedimentary rock Limestone, sandstone, dolomite shale	D	Rockfalls, infrequent slumping Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls flatter talus accumulation at toe Softer shales erode to low angle valley walls (< 35)

NOTES

1 Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments Thicknesses of units not measured

2 Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs

3 Transitions between units are often gradual rather than abrupt, in such instances boundaries are chosen arbitrarily

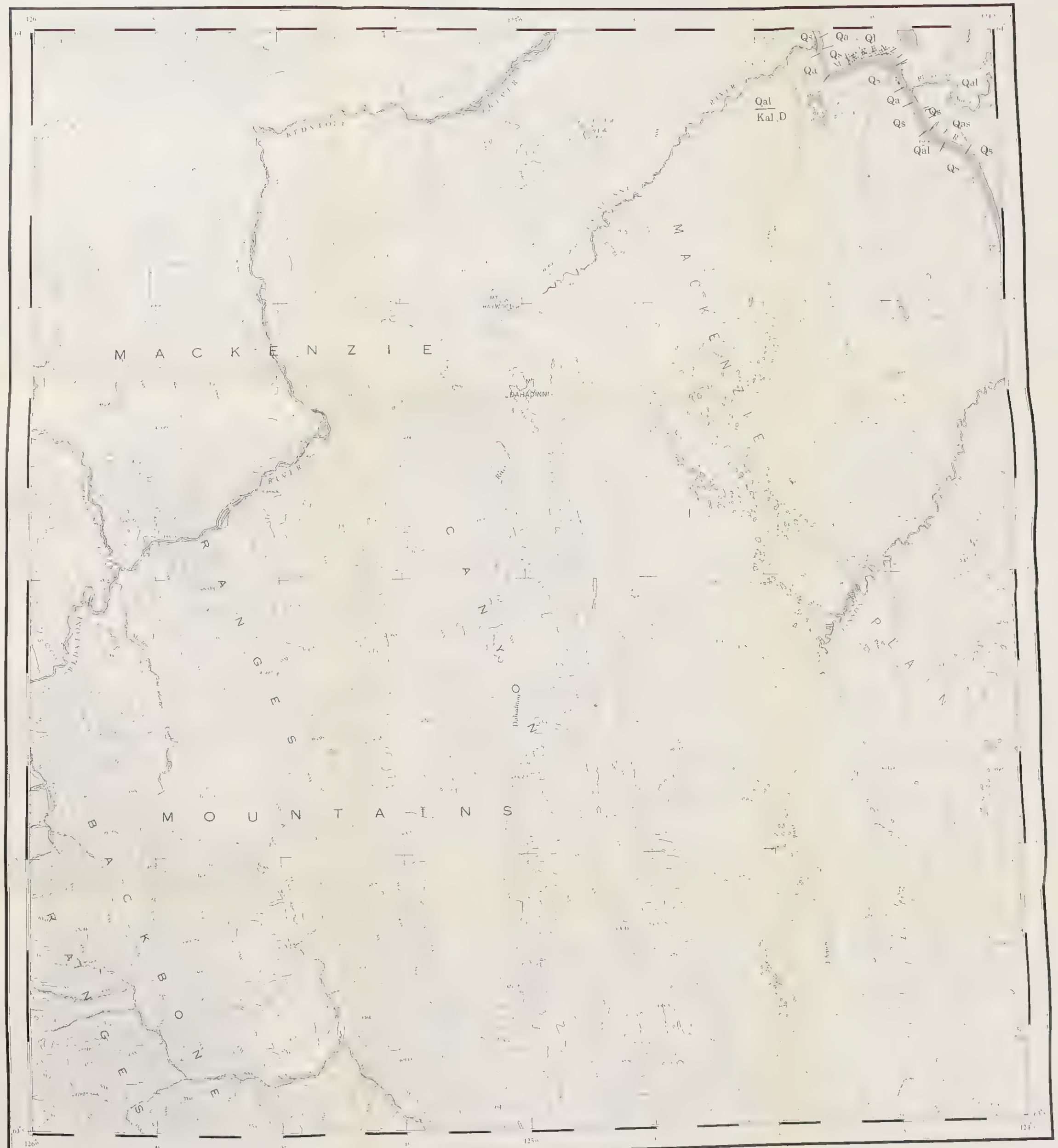
4 Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J A Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES



Surveyed, compiled, drawn and printed by the ARMY SURVEY ESTABLISHMENT, R.C.E.

DAHADINNI RIVER

DISTRICT OF MACKENZIE
NORTHWEST TERRITORIES

Scale 1 : 250,000
1 Inch to 4 Miles approximately

REFERENCE

REFERENCE

Index To Adjoining Sheets

GSC MAP 8-1973

RIVER BANK STABILITY MAP

To accompany

THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible, some mass transport of beach and lower slope material by water and river ice	Stable slopes, vegetated usually 15° or less. Burnt areas unstable at 5° or less
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash	Slope angle 15-35°. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows), usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement, sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone, conglomerate, shale	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope, talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone	Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet. Weathered slopes generally less than 35°
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°)

NOTES

1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs
3. Transitions between units are often gradual rather than abrupt; In such instances boundaries are chosen arbitrarily
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J. A. Code from information collected in 1971-1972

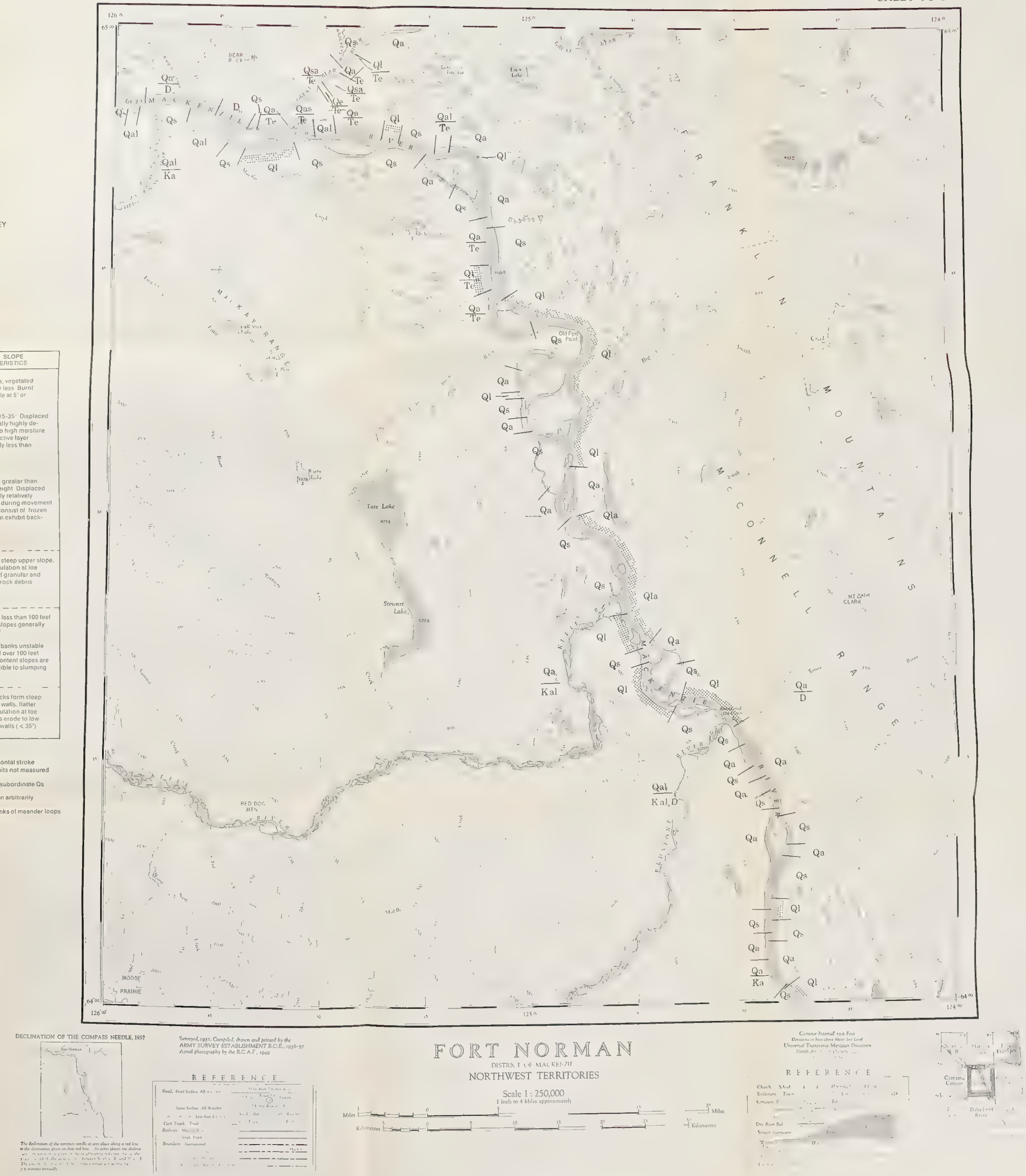
Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA

RIVER BANK STABILITY MAPS

SHEET 96 C



GSC MAP 9 1973

RIVER BANK STABILITY MAP

To accompany

THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

by J A Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
		Qs	Negligible some mass transport of beach and lower slope material by water and river ice	Stable slopes vegetated usually 15° or less Burnt areas unstable at 5 or less.
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments (Soil cover)	Qa	Mass movement confined to active layer Failures also shallow in non-permafrost areas Mainly earthflows, detachment slides, solifluction Gully erosion and slope-wash	Slope angle 15-35 Displaced material usually highly deformed due to high moisture contents in active layer Slopes usually less than 100 feet high
		Ql	Large scale, retrogressive failures (translational slides slumps, flows), usually accompanied by large scale gullying Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands	Steep slopes greater than 100 feet in height Displaced blocks usually relatively undeformed during movement sometimes consist of frozen soil and often exhibit backward tilt
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone conglomerate shale	Te	Gullying, slope wash, infrequent slumping	Moderate to steep upper slope talus accumulation at toe consisting of granular and fragmented rock debris
Cretaceous	Weak soft shale, weakly cemented sandstone and siltstone	Ka	Gullying, slope wash shallow active layer slides	Bank height less than 100 feet Weathered slopes generally less than 35
		Kl	Large scale retrogressive failures of high shale banks	Steep shale banks unstable at heights of over 100 feet Low shale content slopes are less susceptible to slumping
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock Limestone, sandstone, dolomite shale	D	Rockfalls infrequent slumping Some high shale content banks more susceptibe to gullying and slumping	Resistant rocks form steep upper valley walls flatter talus accumulation at toe Softer shales erode to low angle valley walls (< 35)

NOTES

1 Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments Thicknesses of units not measured

2 Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs

3. Transitions between units are often gradual rather than abrupt, in such instances boundaries are chosen arbitrarily

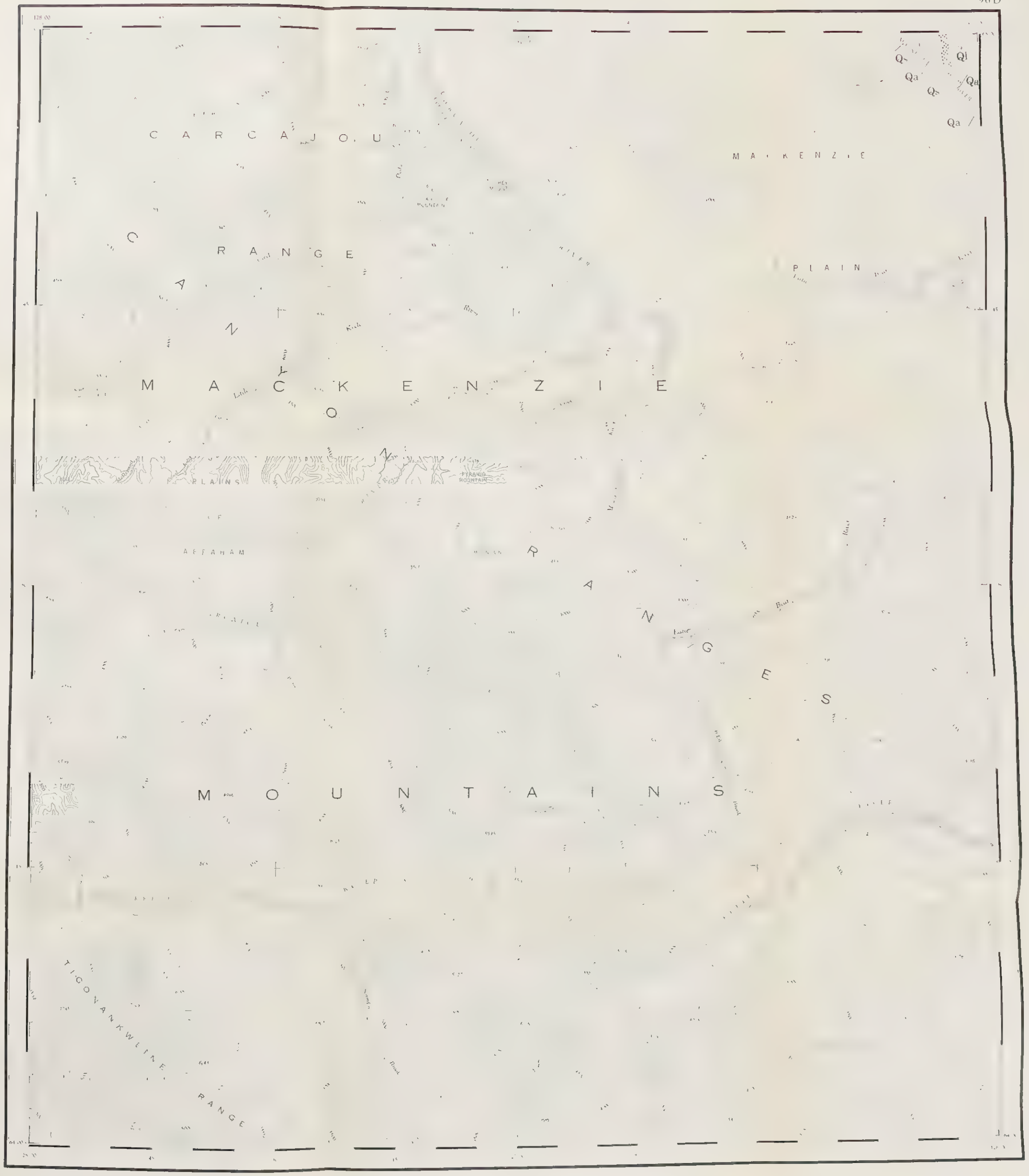
4 Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops

Compiled by J A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA



CARCAJOU CANYON

DISTRICT OF MACKENZIE

NORTHWEST TERRITORIES

Scale 1:250,000 Échelle

Miles 0 5 10 15 20 Miles

Kilometres 0 5 10 15 20 25 30 Kilometres

Transverse Mercator Projection
North American Datum 1927
Contour Interval 500 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Réseau géodésique nord-américain de 1927
Equidistance des courbes 500 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

GSC MAP 10-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qs	Negligible, some mass transport of beach and lower slope material by water and river ice.	Stable slopes, vegetated, usually 15° or less. Burnt areas unstable at 5° or less.
		Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash.	Slope angle 15-35°. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high.
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows); usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands.	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement; sometimes consist of frozen soil and often exhibit backward tilt.
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone, conglomerate, shale.	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope; talus accumulation at toe consisting of granular and fragmented rock debris.
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone.	Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet. Weathered slopes generally less than 35°.
		Kl	Large scale retrogressive failures of high shale banks.	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping.
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptibe to gullying and slumping.	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°).

NOTES

1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured.
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs.
3. Transitions between units are often gradual rather than abrupt; in such instances boundaries are chosen arbitrarily.
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops.

Compiled by J.A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES

96 E

NORMAN WELLS

NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE

Scale 1:250,000 Échelle

Transverse Mercator Projection
North American Datum 1927
Contour Interval 200 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927
Equidistance des courbes: 200 pieds
Elévations en pieds au-dessus du niveau moyen de la mer

Index to adjoining sheets of National Topographic System
Tableau d'assemblage du Système de Référence Cartographique National

GSC MAP 11-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qs	Negligible, some mass transport of beach and lower slope material by water and river ice.	Stable slopes, vegetated, usually 15° or less. Burnt areas unstable at 5° or less.
		Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash.	Slope angle 15-35°. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high.
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows); usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands.	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement; sometimes consist of frozen soil and often exhibit backward tilt.
Tertiary	Weakly cemented, mainly clastic sediments-sandstone, limestone, conglomerate, shale.	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope; talus accumulation at toe consisting of granular and fragmented rock debris.
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone.	Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet. Weathered slopes generally less than 35°.
		Kl	Large scale retrogressive failures of high shale banks.	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping.
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptibe to gullying and slumping.	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°).

NOTES

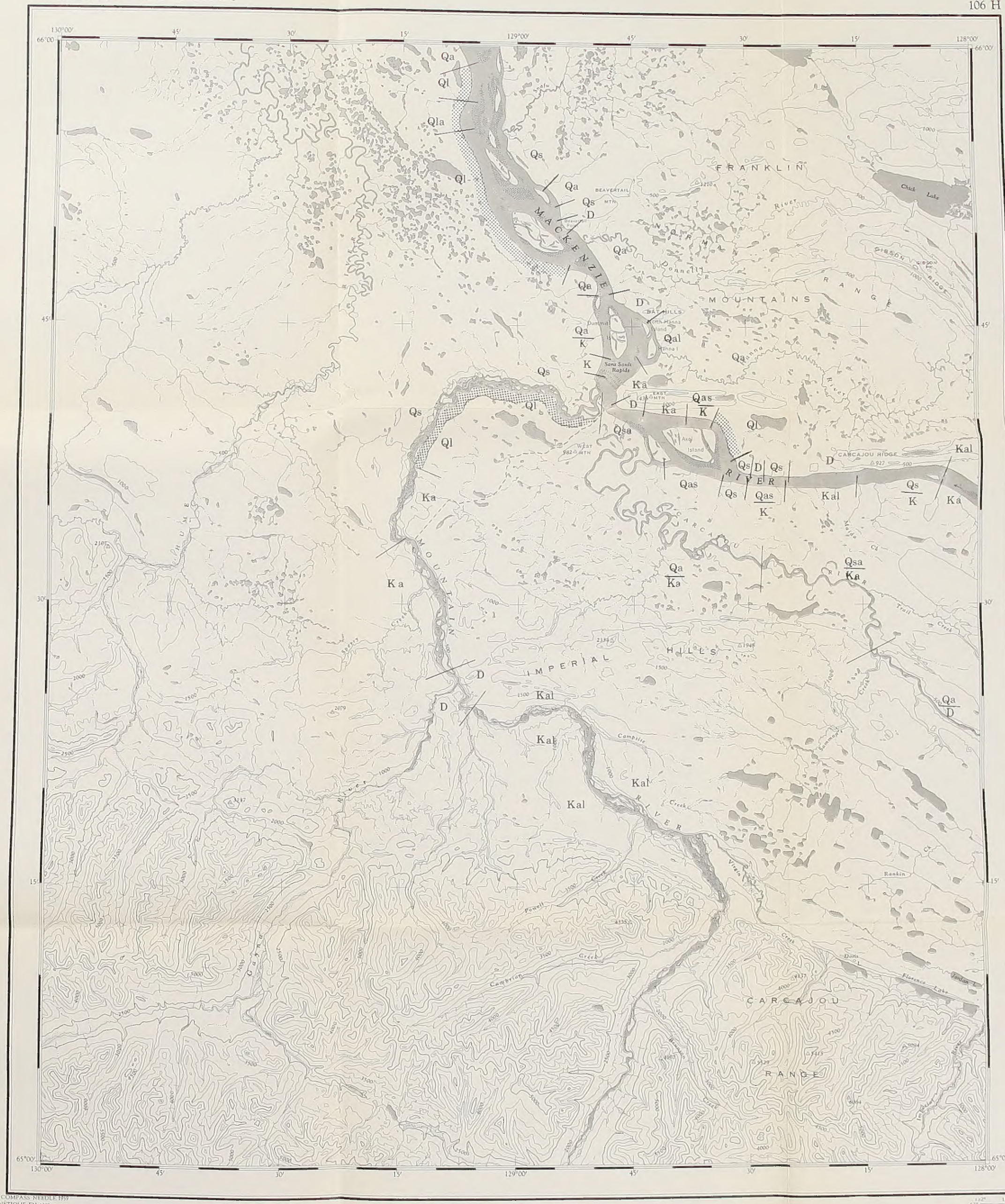
1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured.
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs.
3. *Transitions between units are often gradual rather than abrupt; in such instances boundaries are chosen arbitrarily.*
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops.

Compiled by J.A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES



THE DECLINATION OF THE COMPASS NEEDLE 1959
DECLINAISON MAGNÉTIQUE EN 1959

The declination of the compass needle is decreasing 7 minutes annually
La déclinaison magnétique décroît de 7 minutes annuellement

SANS SAULT RAPIDS

NORTHWEST TERRITORIES

DISTRICT OF MACKENZIE

Scale 1:250,000 Échelle

Transverse Mercator Projection
North American Datum 1927
Contour Interval 500 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Réseau géodésique nord-américain unifié 1927
Équidistance des courbes: 500 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

Index to adjoining sheets of National Topographic System
Tableau d'assemblage du Système de Référence Cartographique National

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES

GSC MAP 12-1973

RIVER BANK STABILITY MAP

To accompany
THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY
by J.A. Code

Environmental Social Program Report 73-9

Prepared by the Department of Energy, Mines and Resources
for the Environmental-Social Program, Northern Pipelines

LEGEND

GEOLOGIC AGE	DESCRIPTION	MAP NOTATION	MODE OF EROSION	TYPICAL SLOPE CHARACTERISTICS
Quaternary and Recent	Granular and fine grained (cohesive) uncemented clastic sediments. (Soil cover)	Qs	Negligible, some mass transport of beach and lower slope material by water and river ice.	Stable slopes, vegetated, usually 15° or less. Burnt areas unstable at 5° or less.
		Qa	Mass movement confined to active layer. Failures also shallow in non-permafrost areas. Mainly earthflows, detachment slides, solifluction. Gully erosion and slope-wash.	Slope angle 15-35°. Displaced material usually highly deformed due to high moisture contents in active layer. Slopes usually less than 100 feet high.
		Ql	Large scale, retrogressive failures (translational slides, slumps, flows); usually accompanied by large scale gullying. Characteristic of glacio-lacustrine sediments overlain by glaciofluvial sands.	Steep slopes greater than 100 feet in height. Displaced blocks usually relatively undeformed during movement; sometimes consist of frozen soil and often exhibit backward tilt.
Tertiary	Weakly cemented mainly clastic sediments-sandstone, limestone, conglomerate, shale.	Te	Gullying, slope wash, infrequent slumping.	Moderate to steep upper slope; talus accumulation at toe consisting of granular and fragmented rock debris.
Cretaceous	Weak soft shale; weakly cemented sandstone and siltstone.	Ka	Gullying, slope wash, shallow active layer slides.	Bank height less than 100 feet. Weathered slopes generally less than 35°.
		Kl	Large scale retrogressive failures of high shale banks.	Steep shale banks unstable at heights of over 100 feet. Low shale content slopes are less susceptible to slumping.
		K	Undifferentiated	
Devonian	Mainly well cemented, resistant sedimentary rock. Limestone, sandstone, dolomite shale.	D	Rockfalls, infrequent slumping. Some high shale content banks more susceptibe to gullying and slumping.	Resistant rocks form steep upper valley walls, flatter talus accumulation at toe. Softer shales erode to low angle valley walls (< 35°).

NOTES

1. Vertical sequences of the above units observed in the field are shown with components divided by horizontal stroke. For example $\frac{Qa}{K}$ denotes Quaternary with shallow slides over Cretaceous sediments. Thicknesses of units not measured.
2. Notations showing combinations of above subdivisions such as Qas indicate predominance of Qa with subordinate Qs.
3. *Transitions between units are often gradual rather than abrupt; in such instances boundaries are chosen arbitrarily.*
4. Where the above notation is applied to meandering rivers, instability if indicated applies only to outside banks of meander loops.

Compiled by J.A. Code from information collected in 1971-1972

Cartography by Geological Survey of Canada

Printed by Surveys and Mapping Branch 1973

RIVER BANK STABILITY MAPS

SHEET 106-I

Transverse Mercator Projection

Contour Interval 100 Feet
Elevations in Feet above Mean Sea Level
North American Datum 1927.

FORT GOOD HOPE

NORTHWEST TERRITORIES

DISTRICT OF MACKENZIE

Scale 1:250,000
1 Inch to 4 Miles Approximately

Miles 5 0 5 10 15 20 Miles
Kilometres 5 0 5 10 15 20 25 30 Kilometres

REFERENCE

Wagon or winter road
Trail or portage
Village or settlement
Post office
Building or cabin
Horizontal control point
Astronomical position
Spot elevation (in feet) 2550.
R.C.M.P. post

REFERENCE

Streams:
intermittent or dry
Intermittent lake
Rapids, falls
Marsh or swamp
Contours:
elevation
depression
approximate
Esker

Index to adjoining sheets